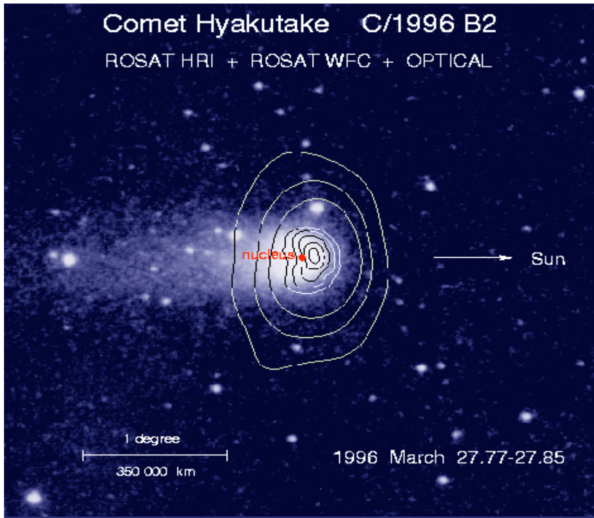
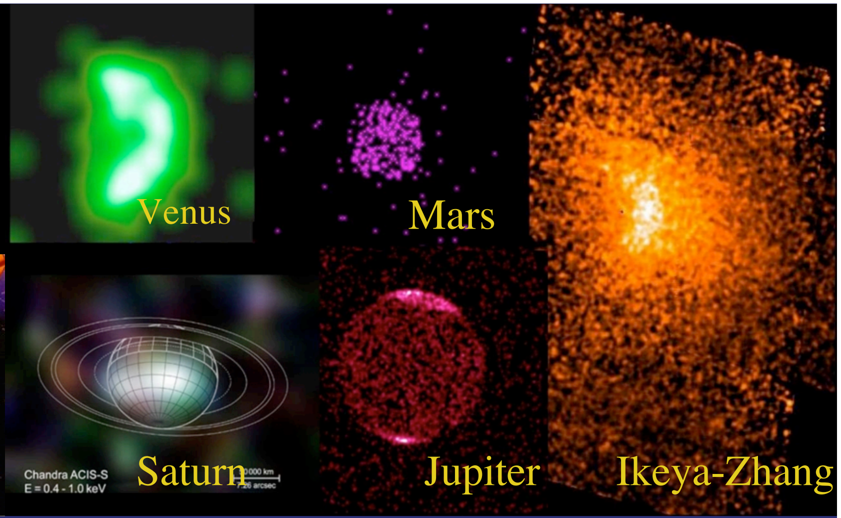
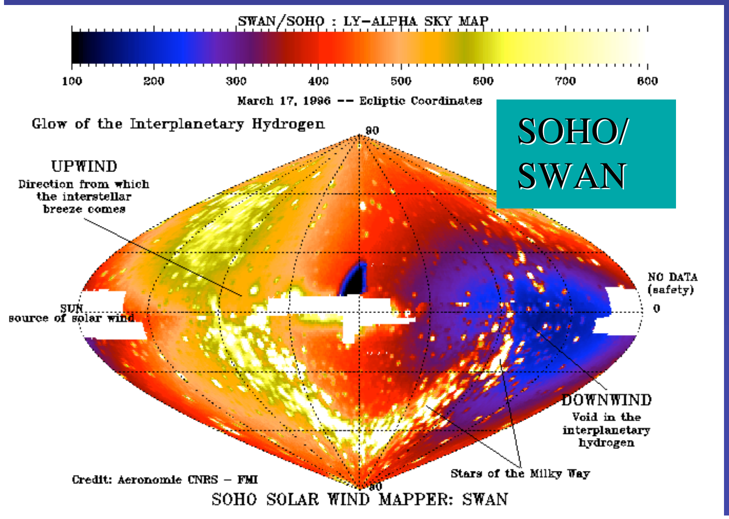


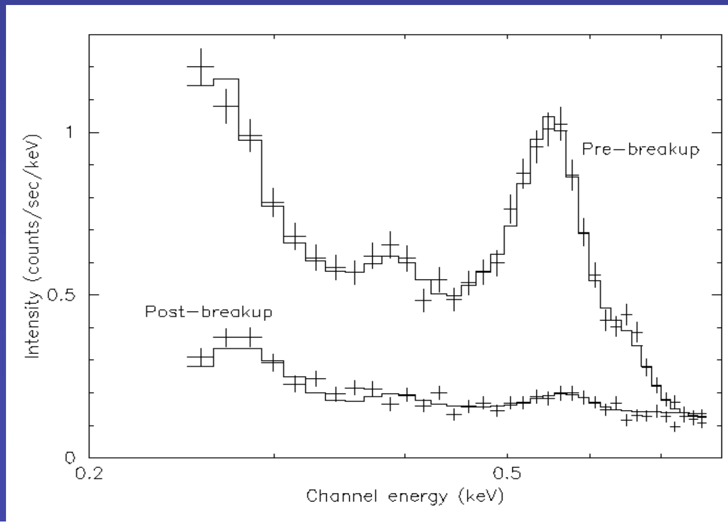


CONX & Solar System X-ray Astronomy : Panel Report

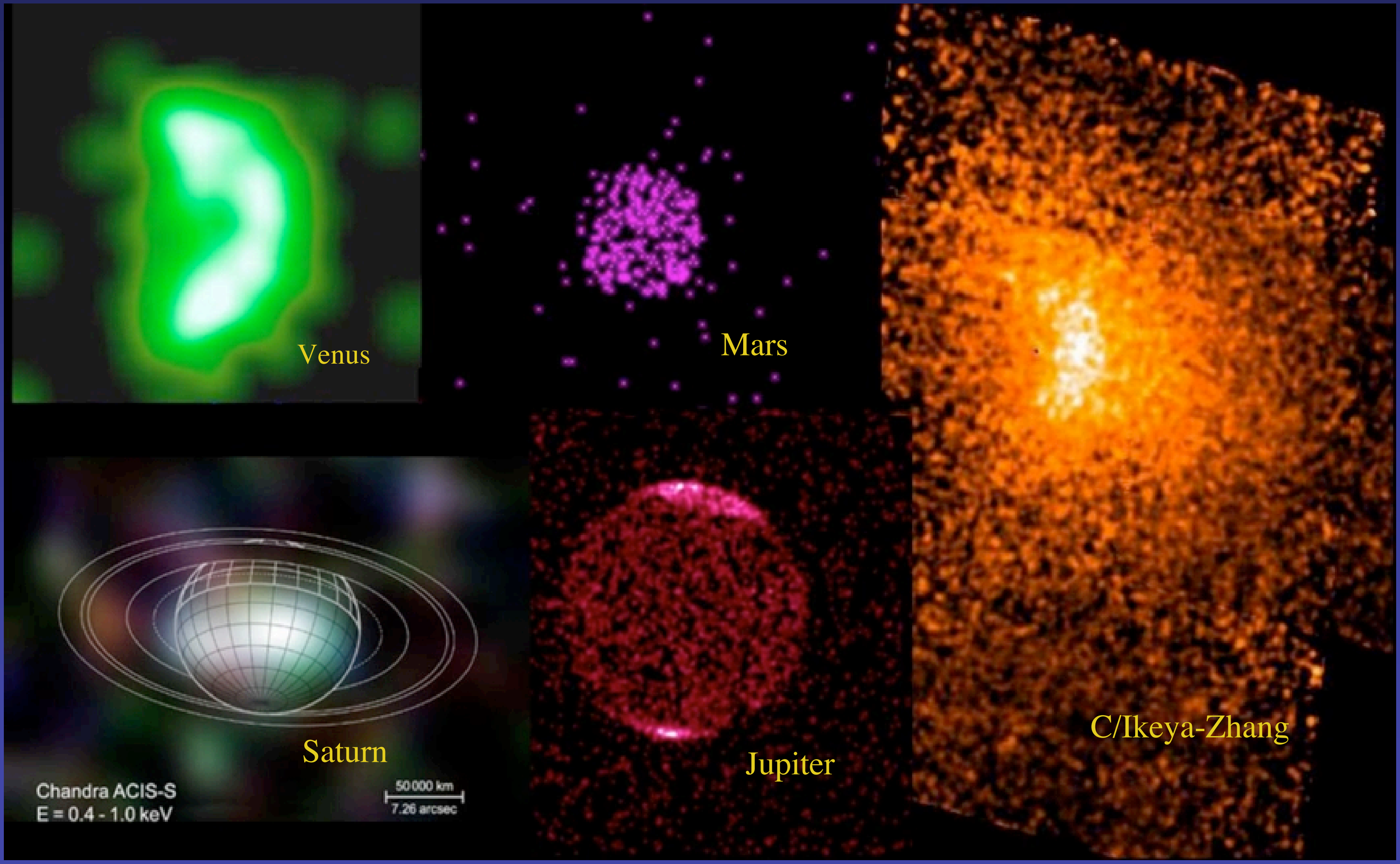
C. M. Lisse, University of Maryland

CONX FST , Greenbelt, MD, USA, May 5, 2004





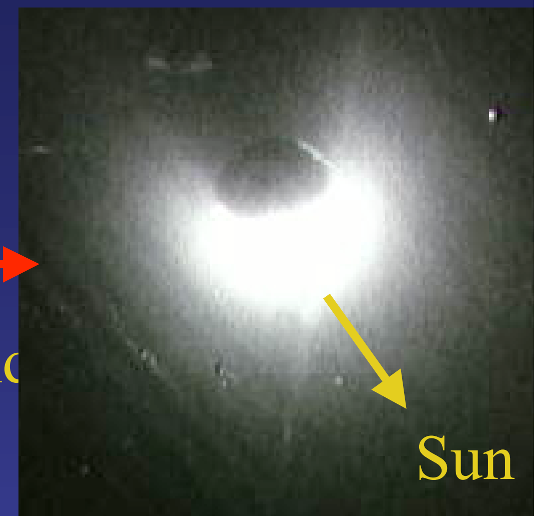
What CONX Can Do : Current renaissance in Solar System x-ray astronomy, but many questions remain…

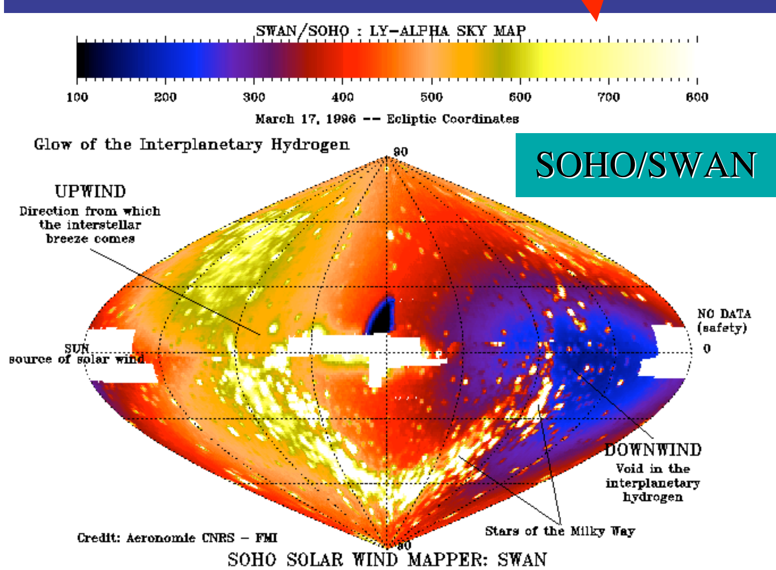


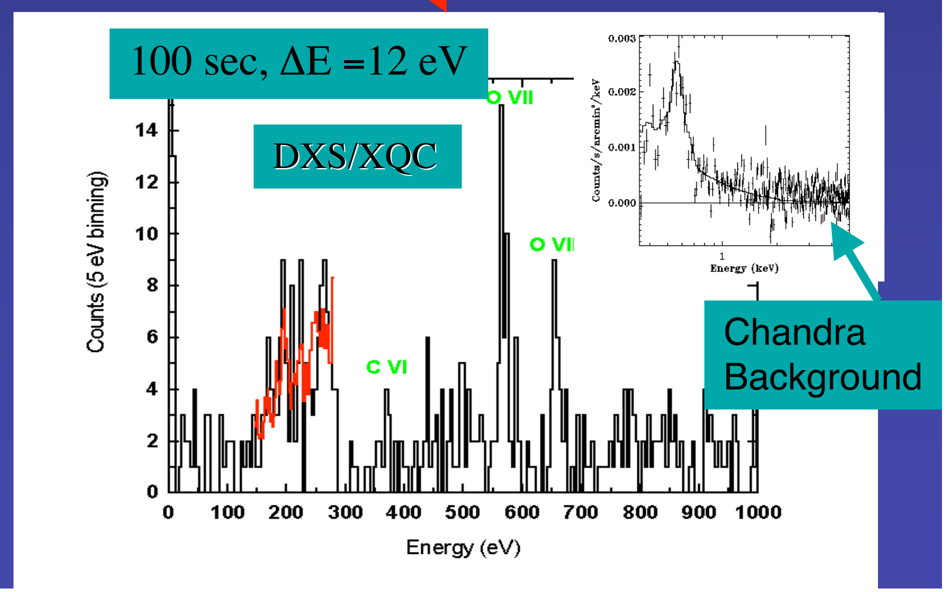
Solar System X-Ray Emission & the new Exploration Initiative

- X-ray emission from any Solar System extended atmosphere, but not solid surfaces

  => Planetary Atmospheres, Io torus, comets, ISM
- Geocoronal Lyman α, heavy neutrals
- Important contributor to the Soft X-ray Background
- Heliosphere/heliopause imaging, Lyman α
  (Image stellar winds in other astrospheres?)







Evidence for Planetary CXE

Earth & Moon

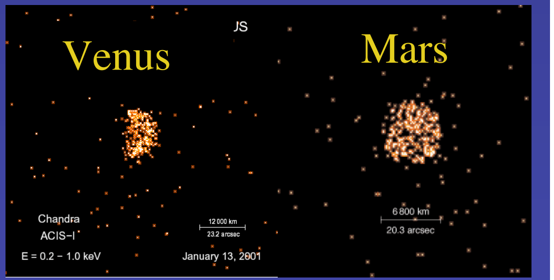
•Atmosphere Explorer C 1974, Arecibo Incoherent Scatter Radar (Maher and Tinsley 1977) of electron and neutral H abundances

•IMAGE/LENA (Low Energy Neutral Atom) imager - response to quiescent solar behavior (Collier et al. 2001)

•IMAGE/HENA (High Energy Neutral Atom) imager - CME response (Brandt 2001)

•Detection of heavy neutral atoms in the Earth's magnetosphere => Interaction of extended, cold H envelope of the Earth with SW via CXE. CXE more important than Jeans escape for terrestrial H loss budget.

•Wargelin et al. 2004 - Lunar emission due to solar insolation + scattering (dayside) + SW-ISM CXE in cislunar space (nightside)

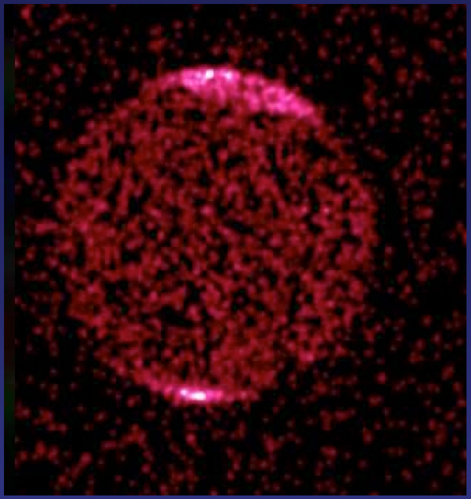


Venus & Mars

•Rusell et al. 1983 : CXE 10x more active at Venus than Mars

•Dennerl et al. 2002, Dennerl 2003 :CXE at Venus negligible, 10-20% of Mars flux

Evidence for Planetary CXE

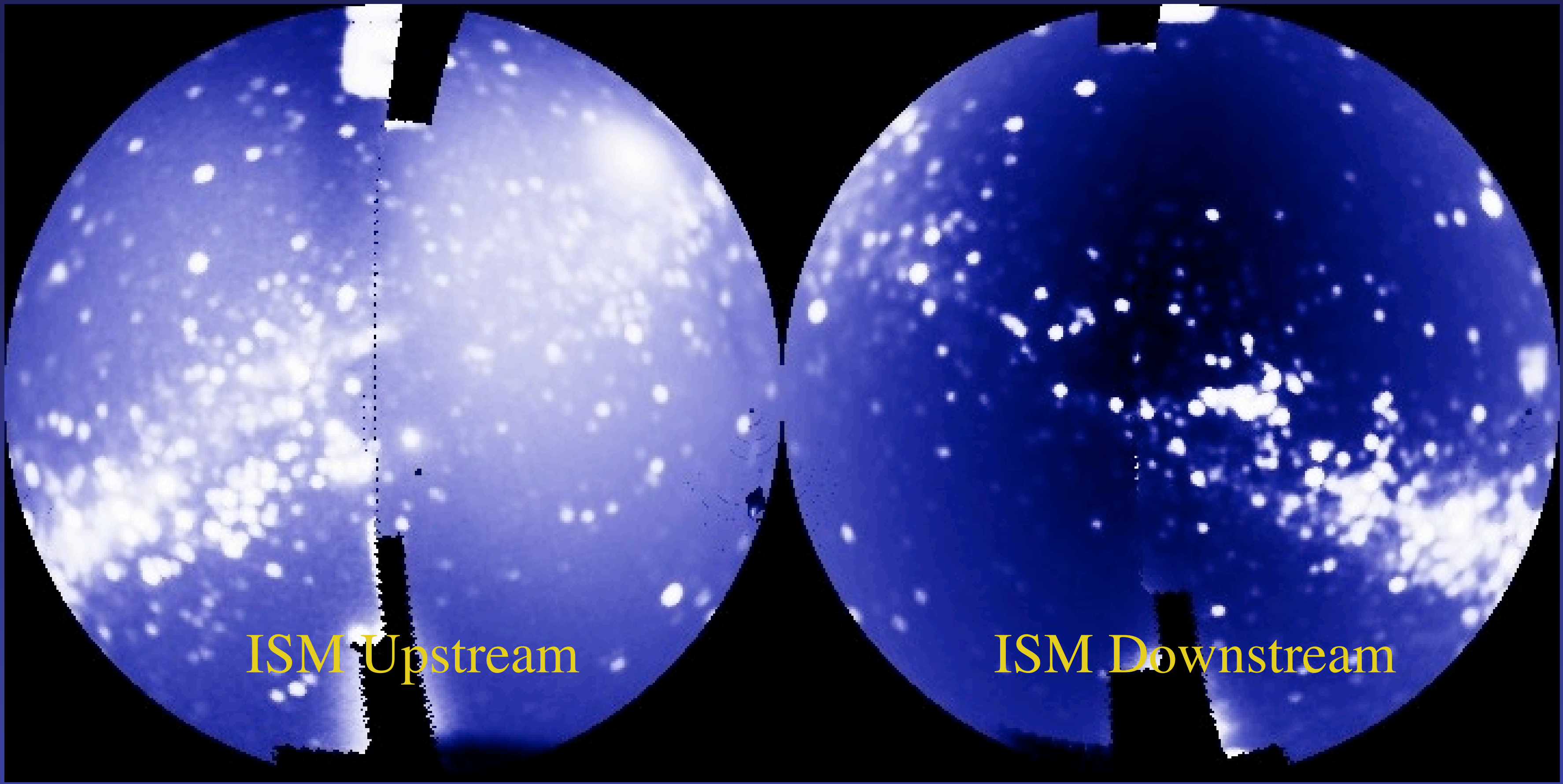


Jupiter

•Sodium CXE in Io flux torus (Smyth and Combi 1991); X-ray emission from Io and Io flux torus (Elsner et al. 2002) ; Europa neutral atom torus (Mauk et al. 2003)

"For Jupiter there are basic questions, such as do the exciting ions originate within the magnetosphere (hence sulfur rich) or within the solar wind (hence relatively carbon rich), that can only be answered with high quality high resolution spectra of the auroral zones relatively uncontaminated by emission from the rest of the disk." - R. Elsner, 2004

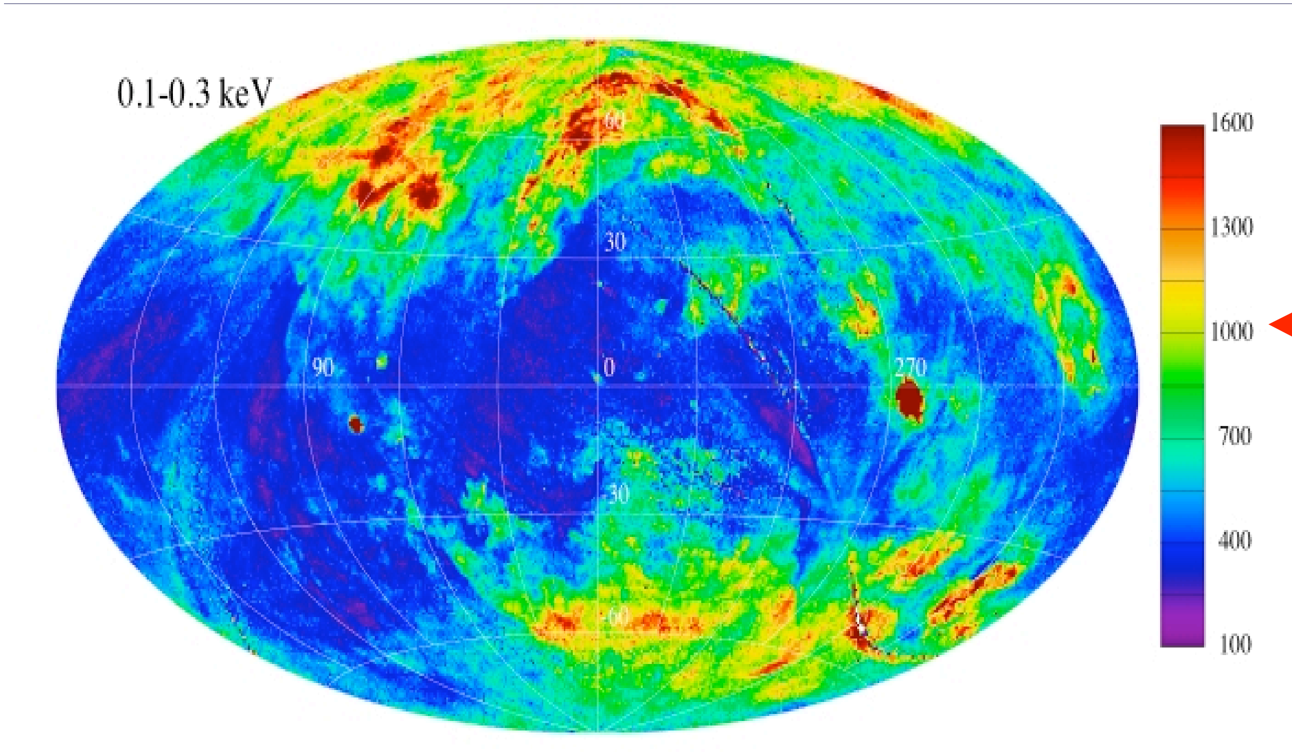
The Instreaming ISM & the SWAN All-sky Ly α

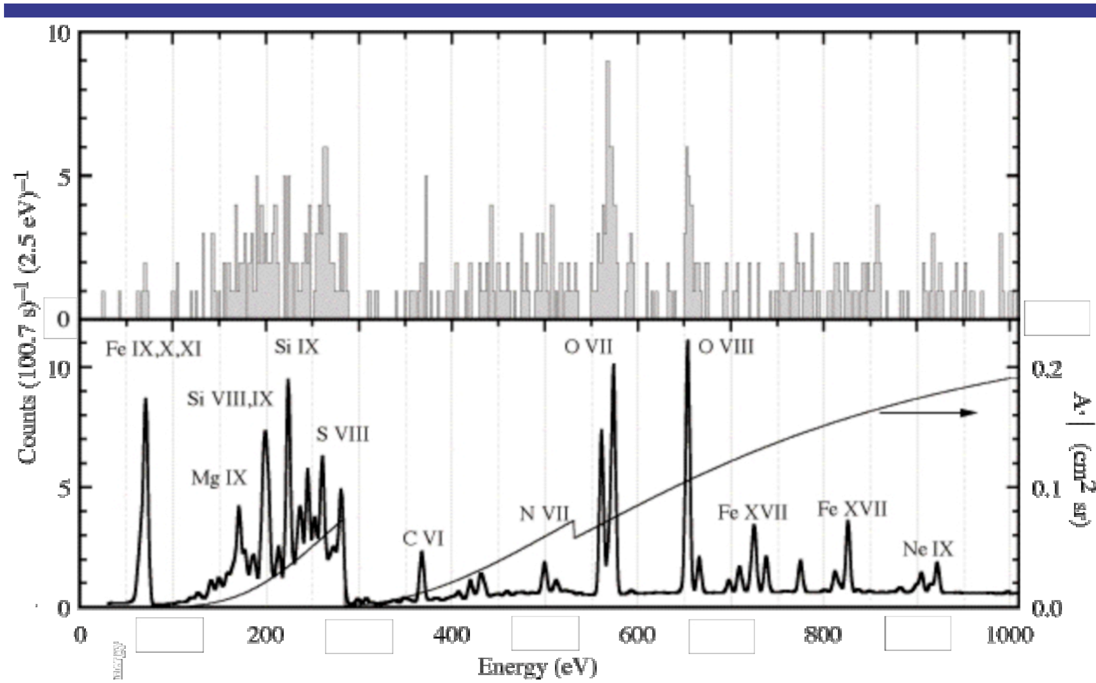


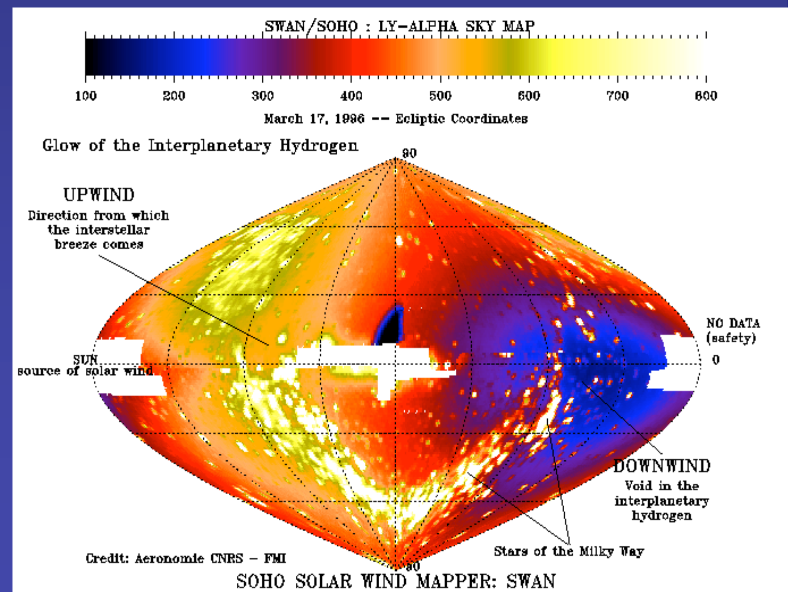
•"The ionization rate of interstellar H atoms by charge exchange with solar wind protons and solar EUV radiation is the main factor governing the H distribution in the solar system, and hence the Lyα emissivity distribution and Lyα emission pattern." - R Lallement et al., A&A 252, 385-401 (1991), from models of Voyager/UVS data

•IMAGE/LENA has detected ISM/SW upstream-downstream asymmetry in heavy neutrals - Collier et al 2001, Moore et al. 2002

Soft x-ray background due to SW-ISM interaction



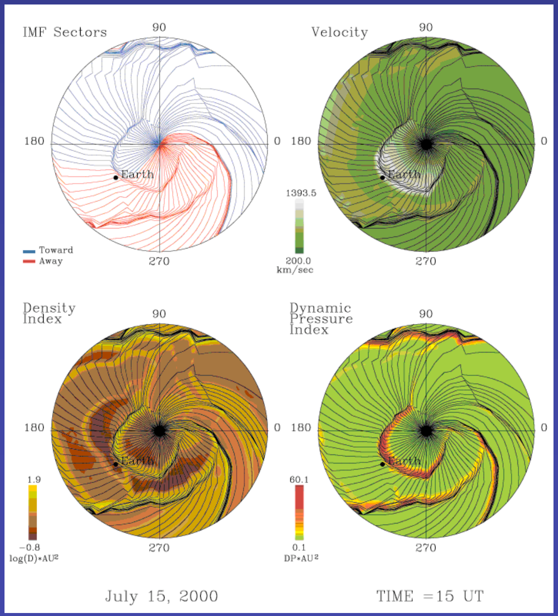


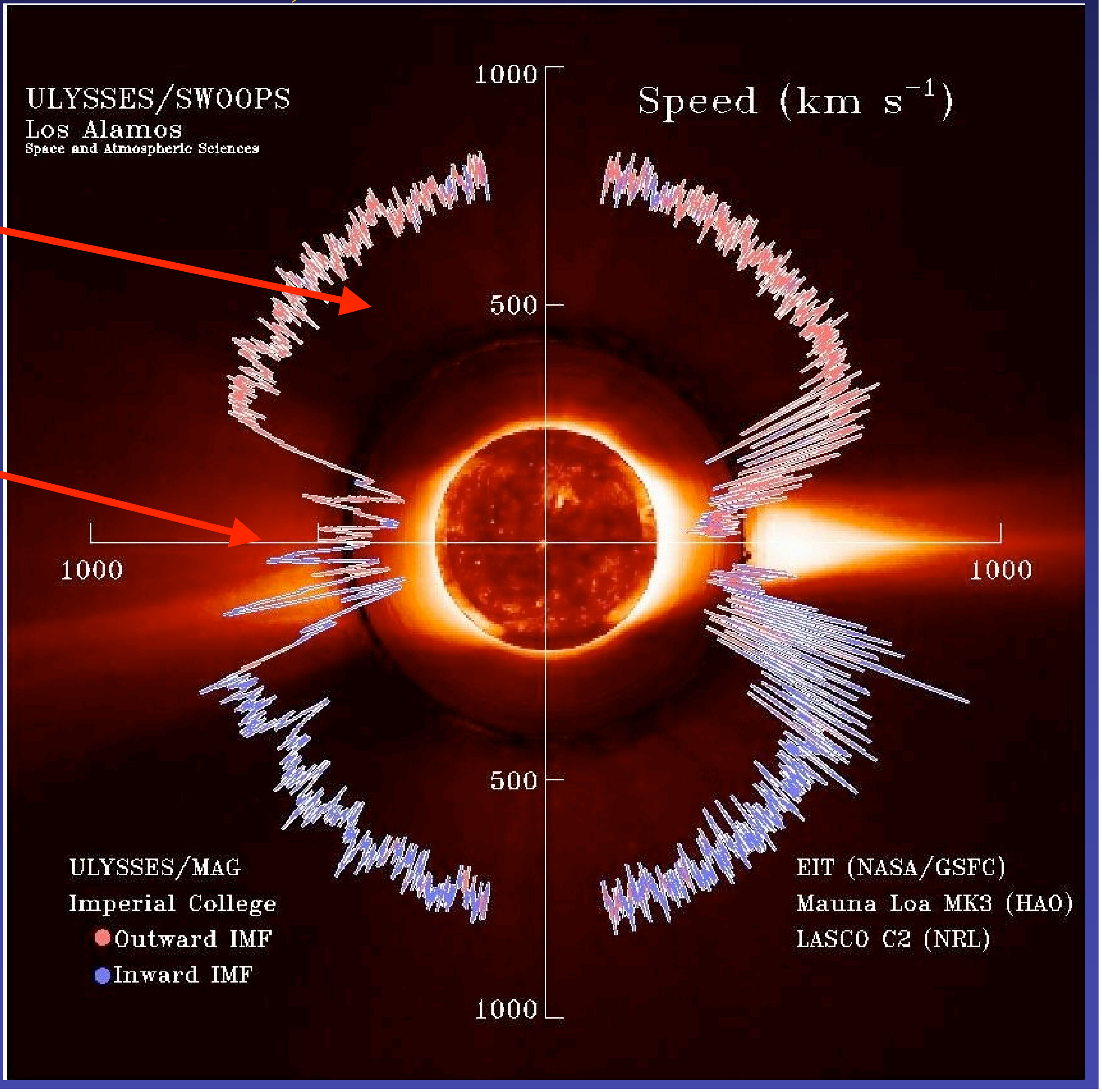


The Source Function : Solar wind (10^6 °K collisional plasma of near solar abundance and few cm^{-3}) and solar insolation

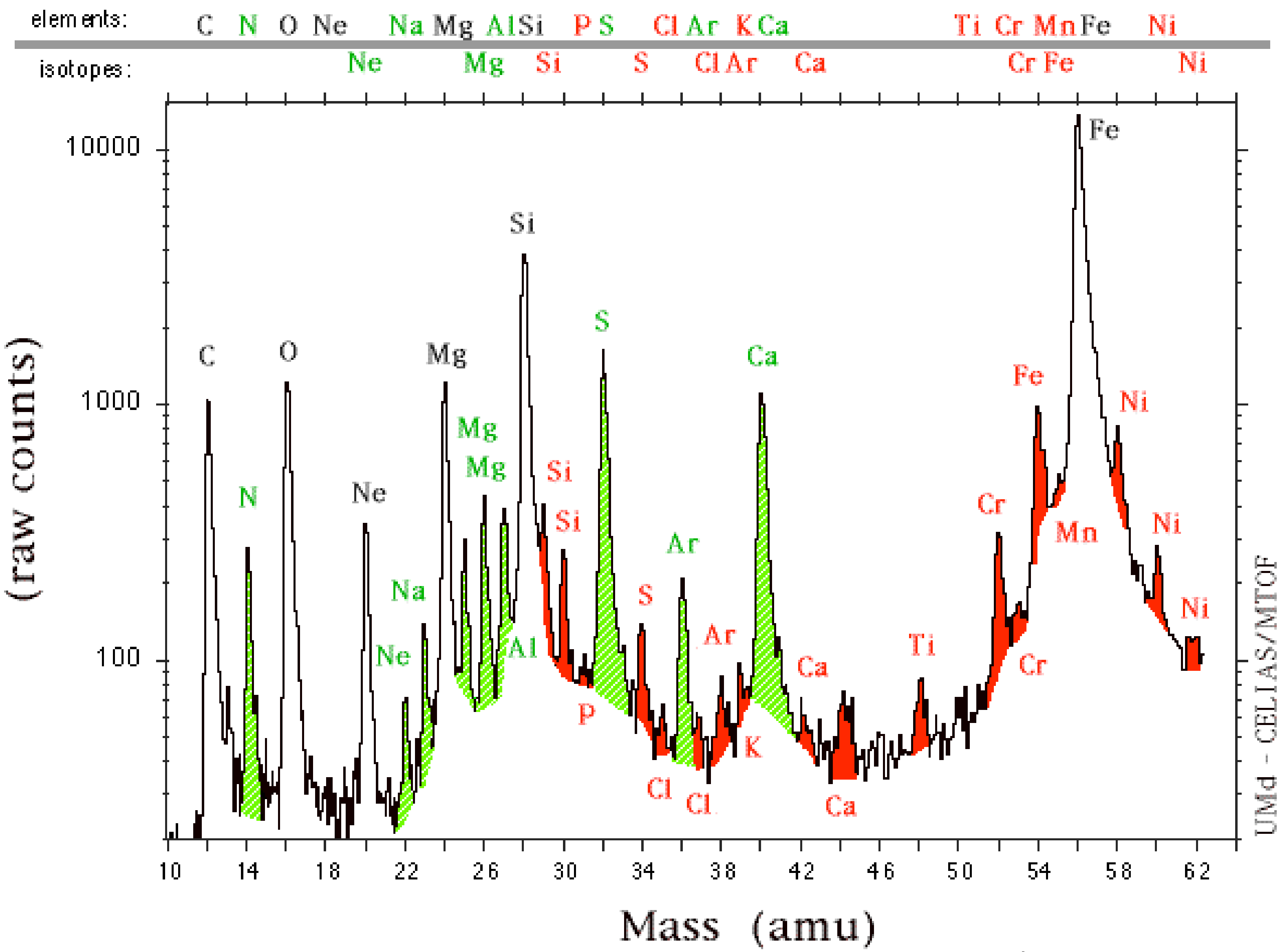
Fast Solar Wind

Slow Solar Wind

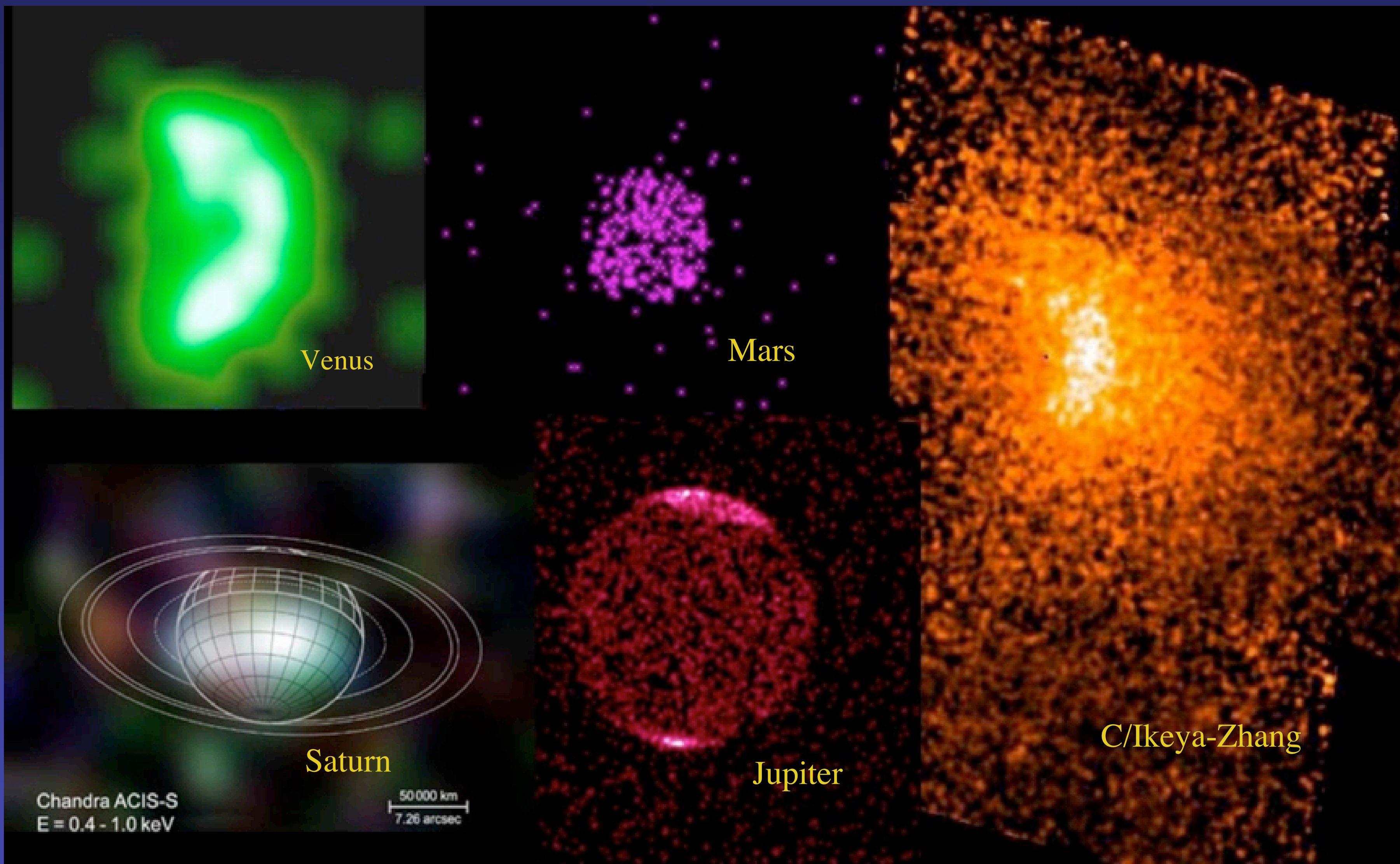




Solar Wind Elements/Isotopes Observed by SOHO/CELIAS

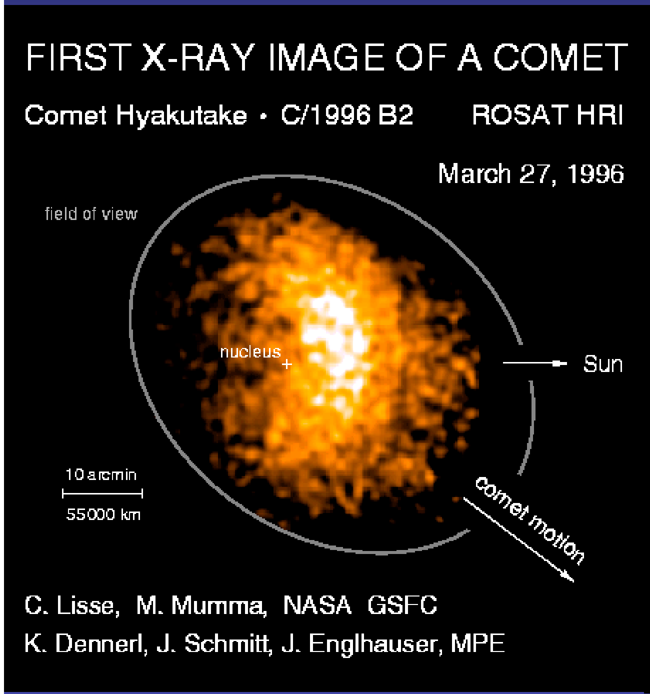


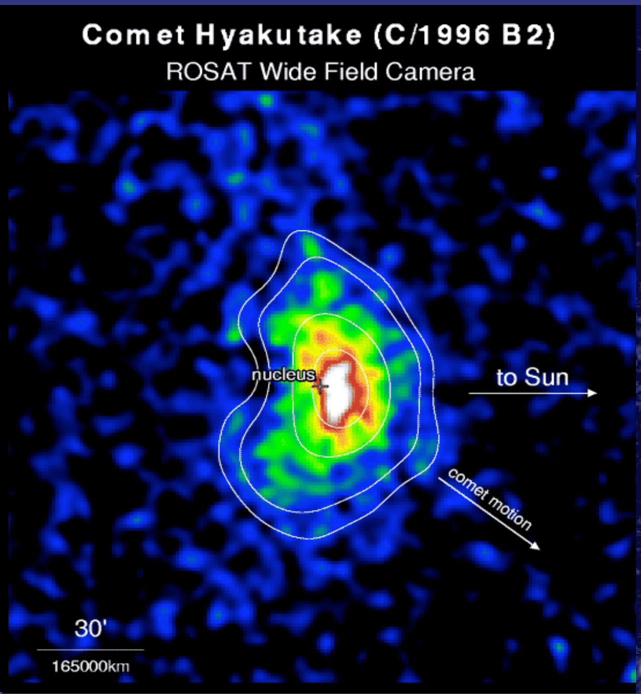
Morphology : Where we are now

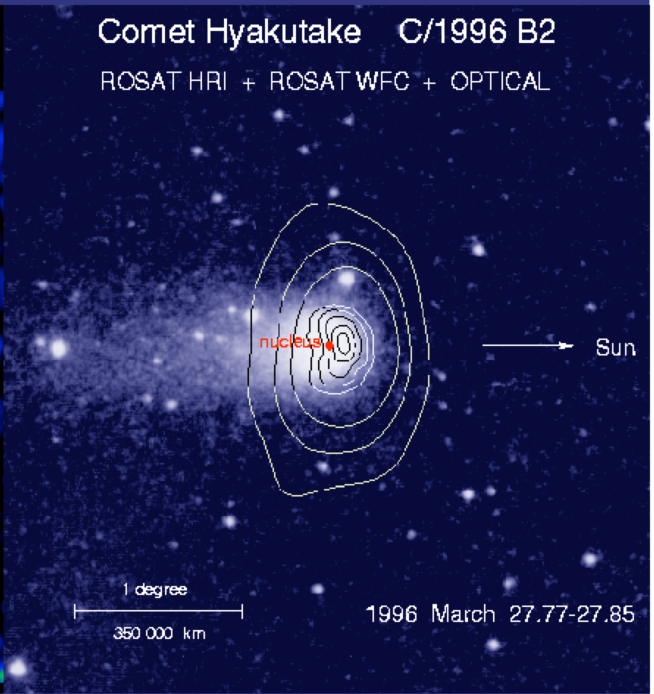


Morphology : Where we are now

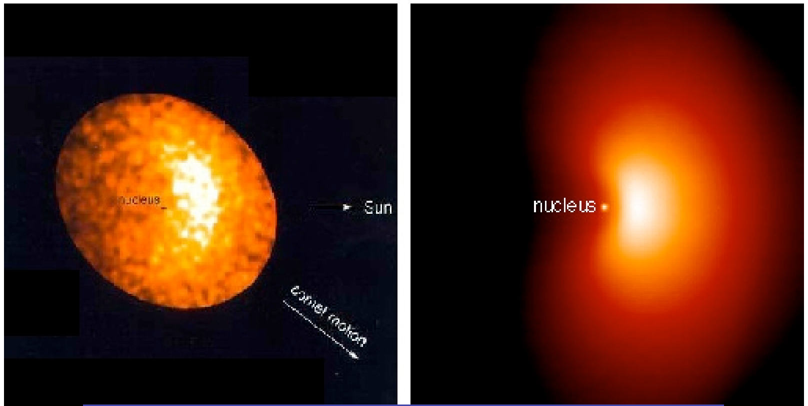
- Similar morphology in X-ray/EUVE
- Symmetry Around the Sun-Nucleus Line
- No Correlation with Comet's Motion - no Ibadov emission





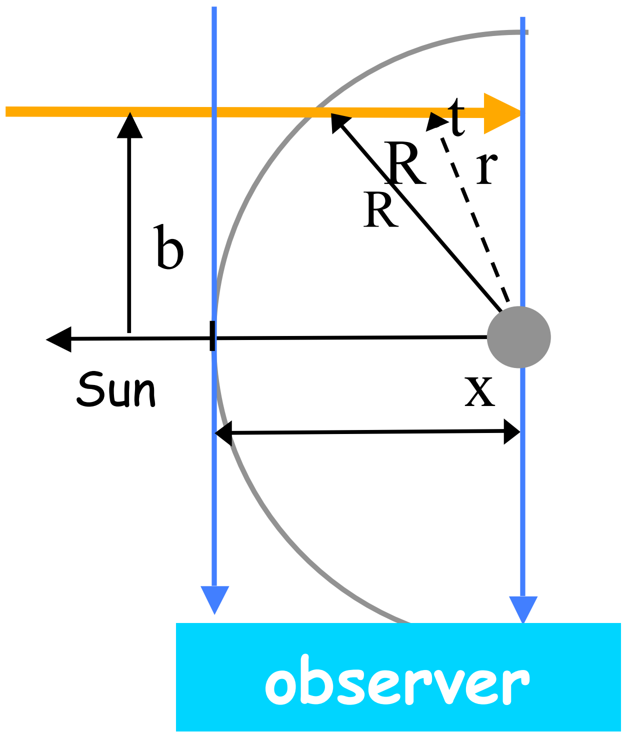


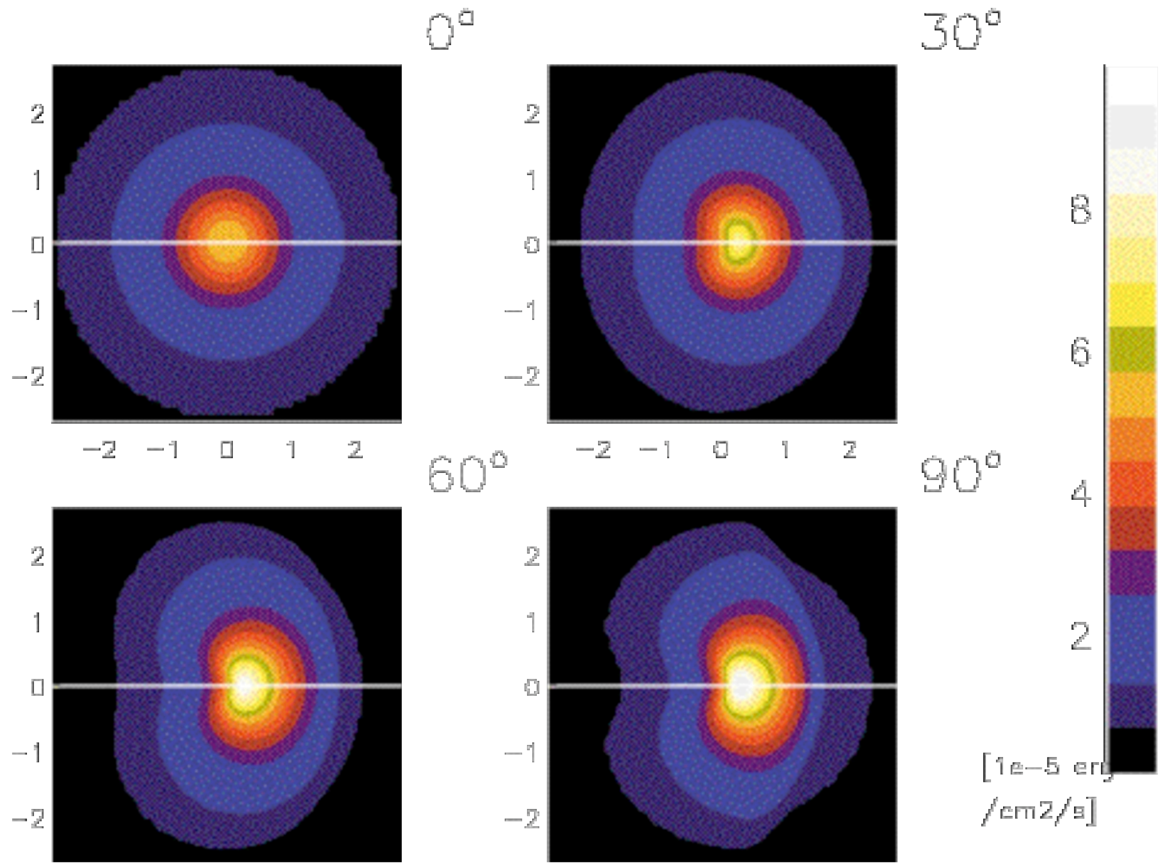
(Lisse et al. 1996)



Hyakutake at 90º phase

Where we would like to be : Understanding the CXE Interaction Cross Section Using the Morphological Variation with Phase Angle

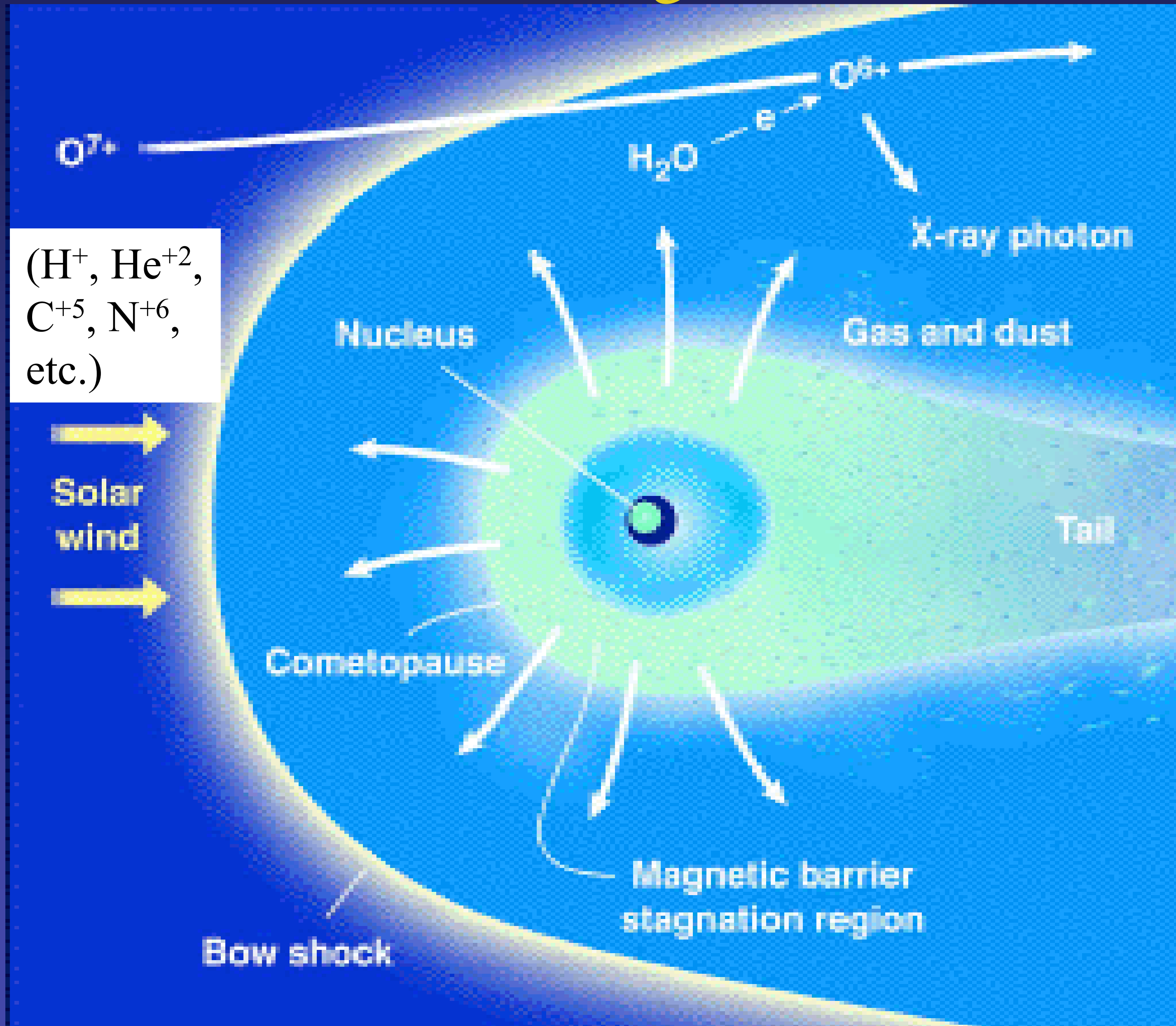




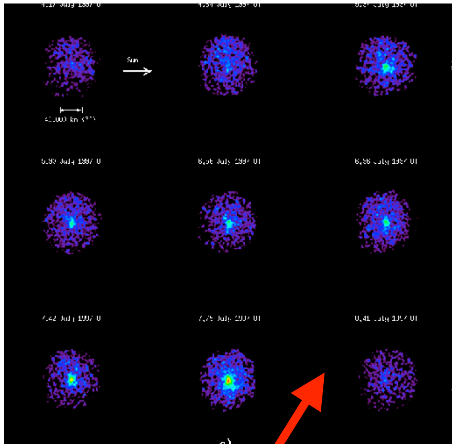
X-ray images are 2-D projection of a 3-D hemispherical shell

R. Wegmann (2003)

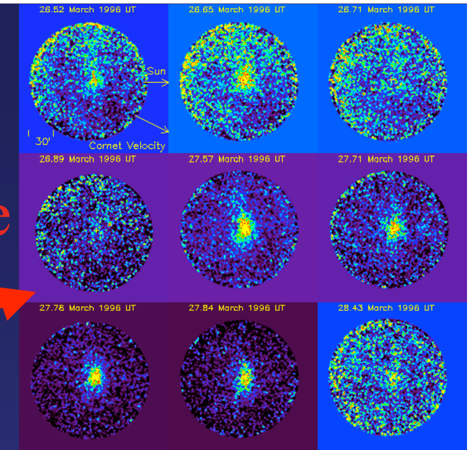
Where we like to be : 100 km resolution imagery of Solar Wind Encountering a Comet + CXE



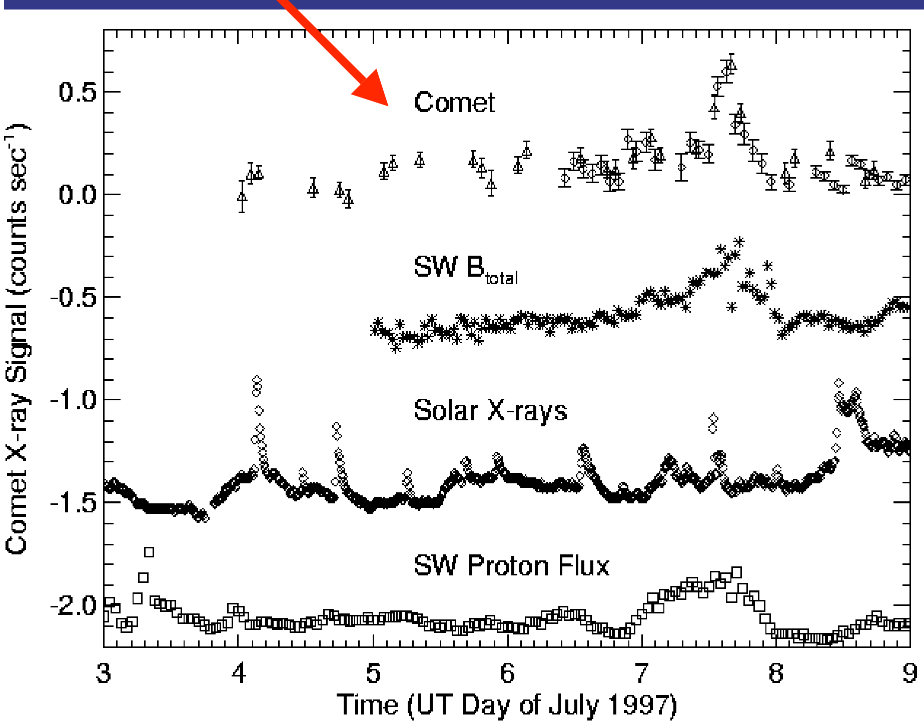
Light Curves: Now

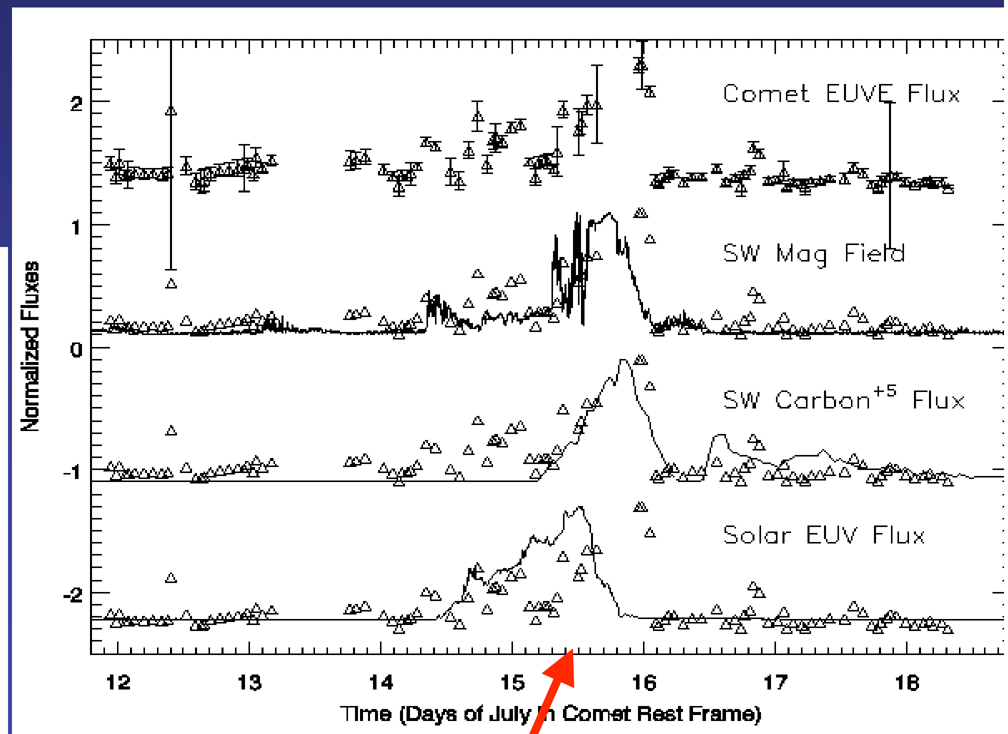


Hyakutake
March
1996



Encke July 1997 w/ Full Carrington Shift

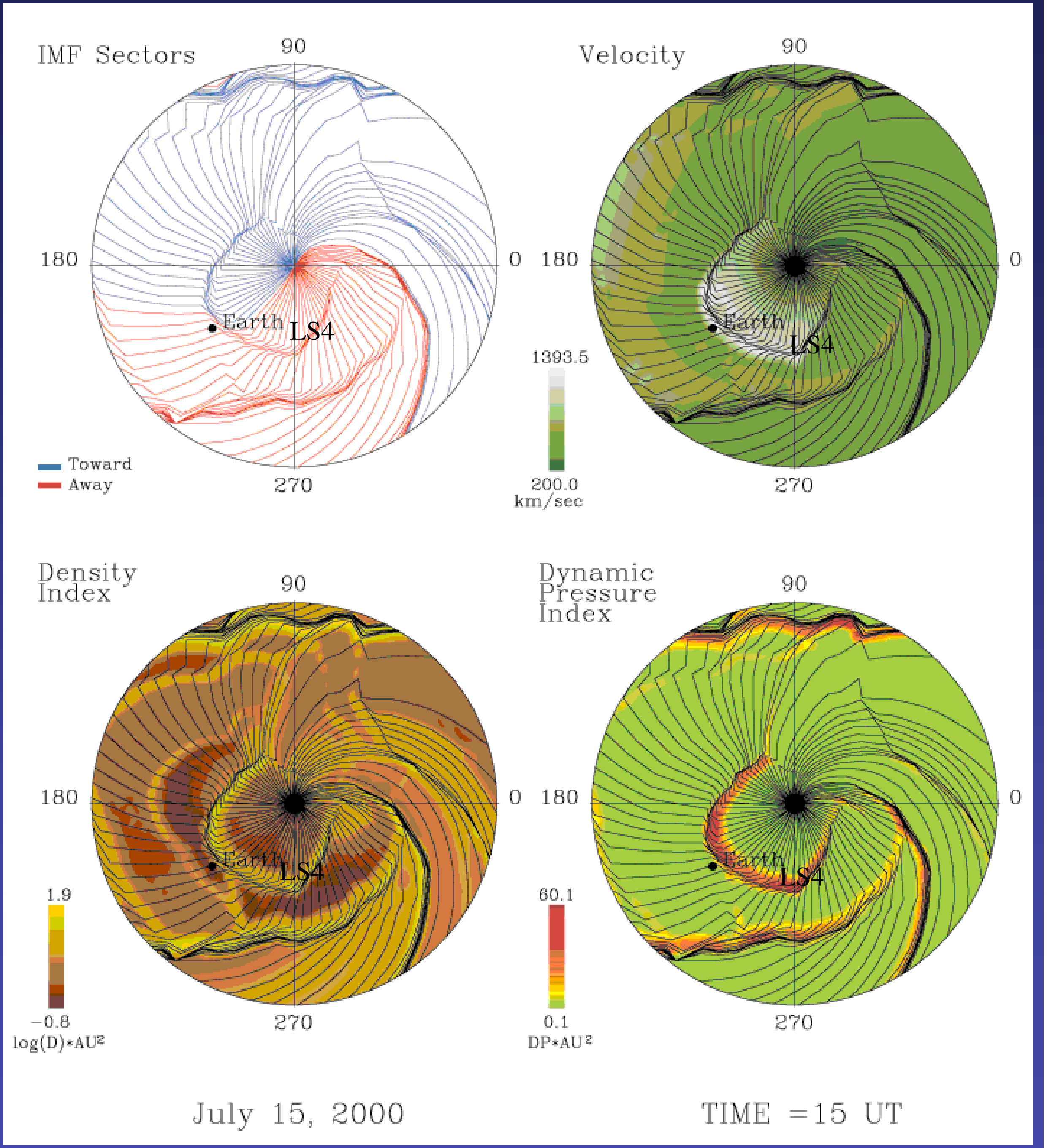




LINEAR 1999 S4 July 2000
Mag Field radial shift ONLY

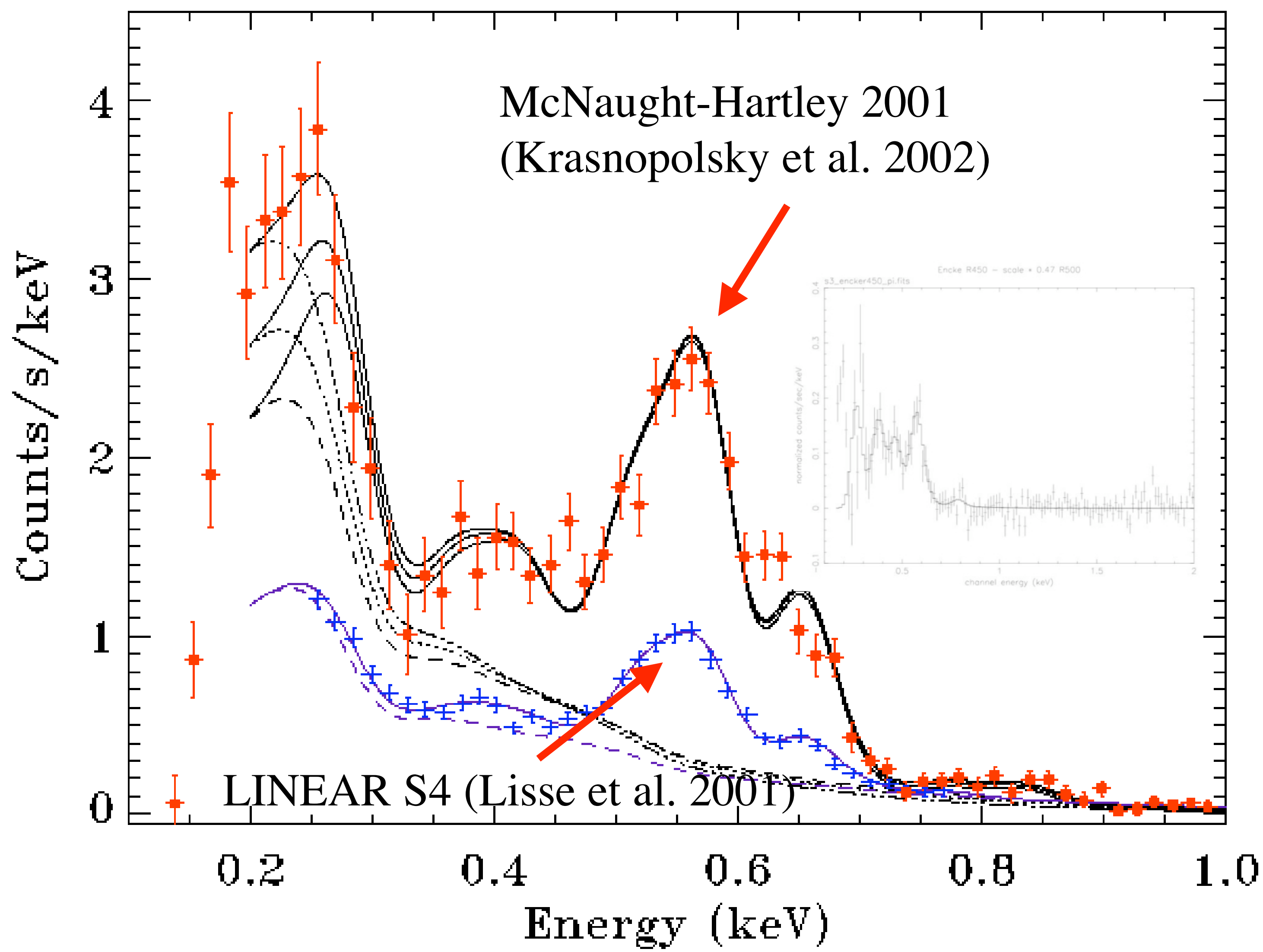
Where we like to be: Space Weather Detection : the 2000 Bastille Day Event & LINEAR S4

The CME was broadcast into a 90º region heading radially from the Sun towards the Earth and C/1999 S4 (LINEAR).

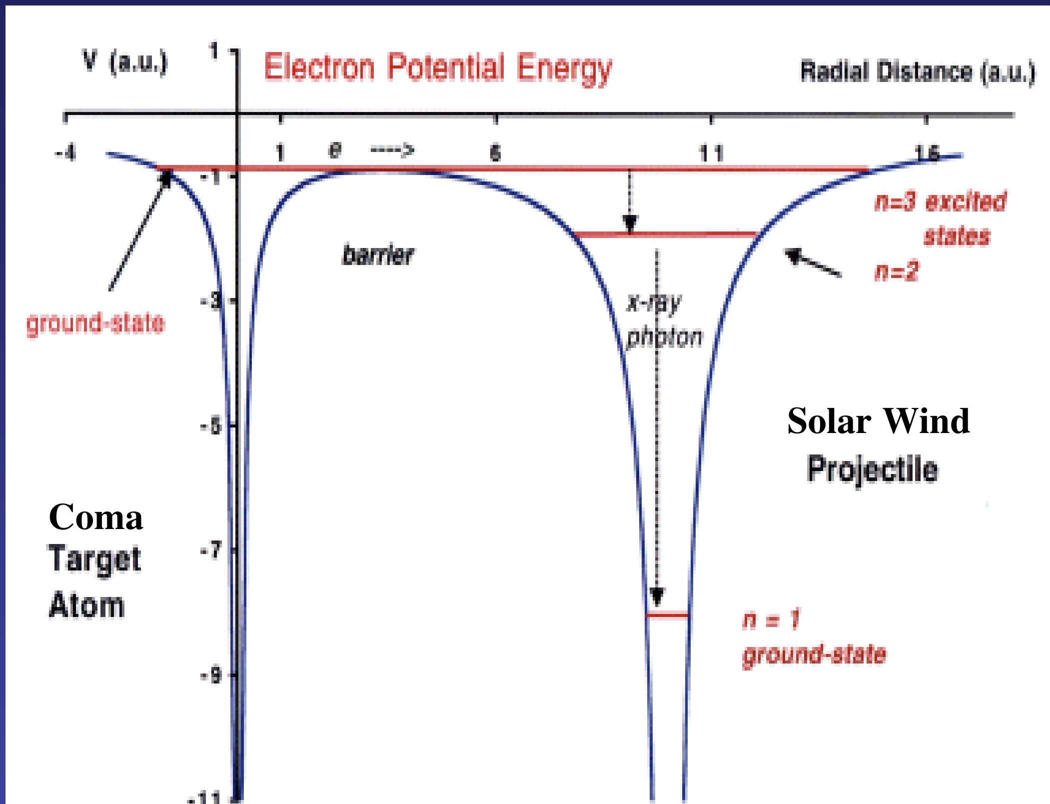


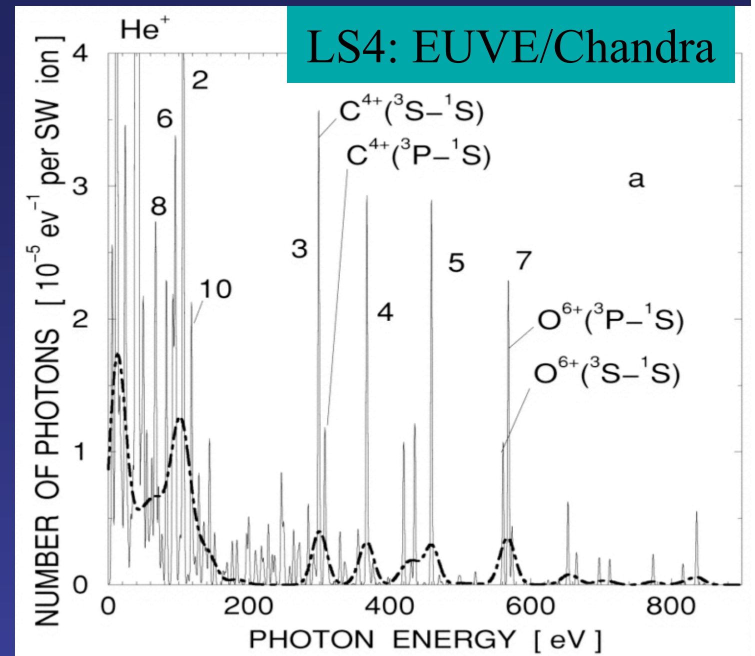
M. Dryer et al., Solar Physics 204: 267-286, 2001

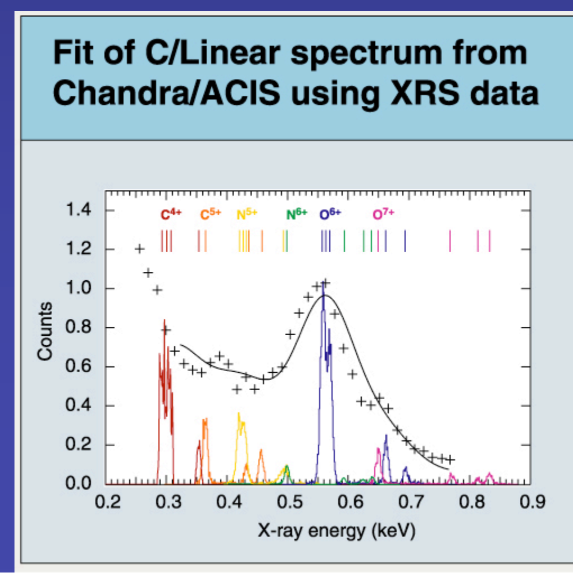
Spectra : Where we are now



Spectral Modeling & Lab Measurements of Cometary CXE





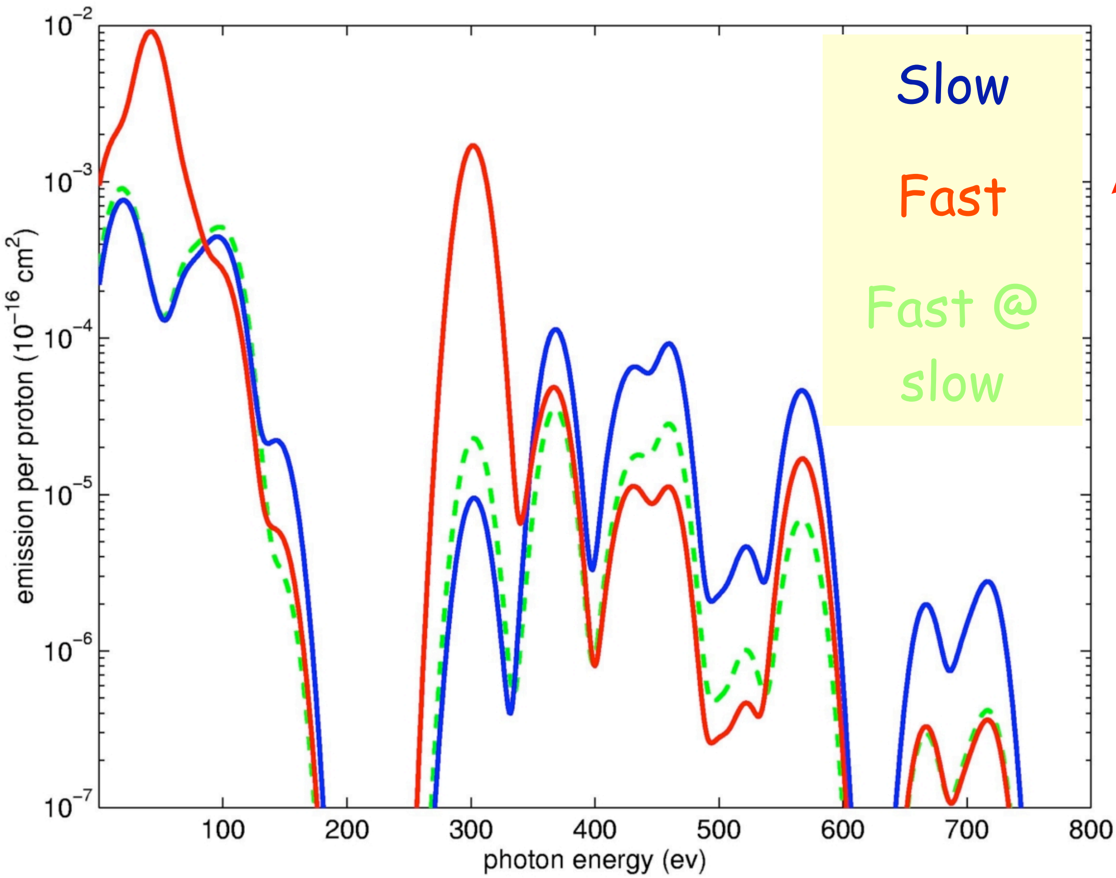


- OVII/OVII line ratios variable
- He^{+},background signal huge at $E < 250$ eV
- All lines, or lines + continuum?
- Fast vs slow solar wind - expect different spectra
- Auger e^{-} quenching on dust, surfaces (Hale-Bopp)?
- Role of Collisions in the cometary atmosphere?

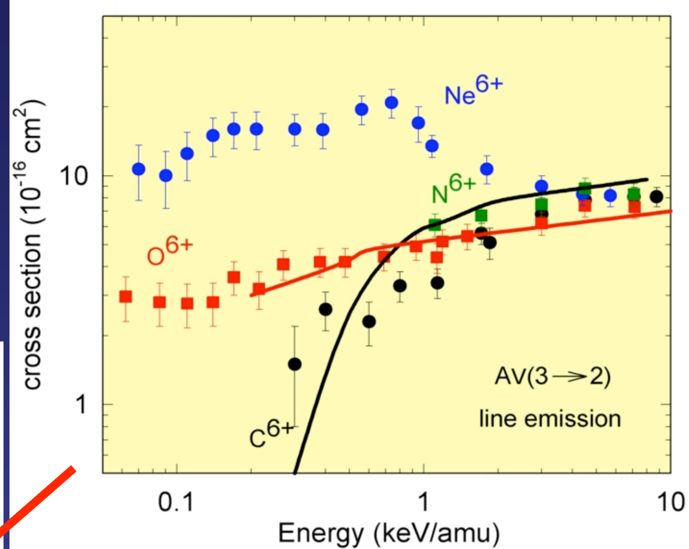
Where we would like to be :

Connection between lab and astronomical measurements

Predicted Line emission spectra

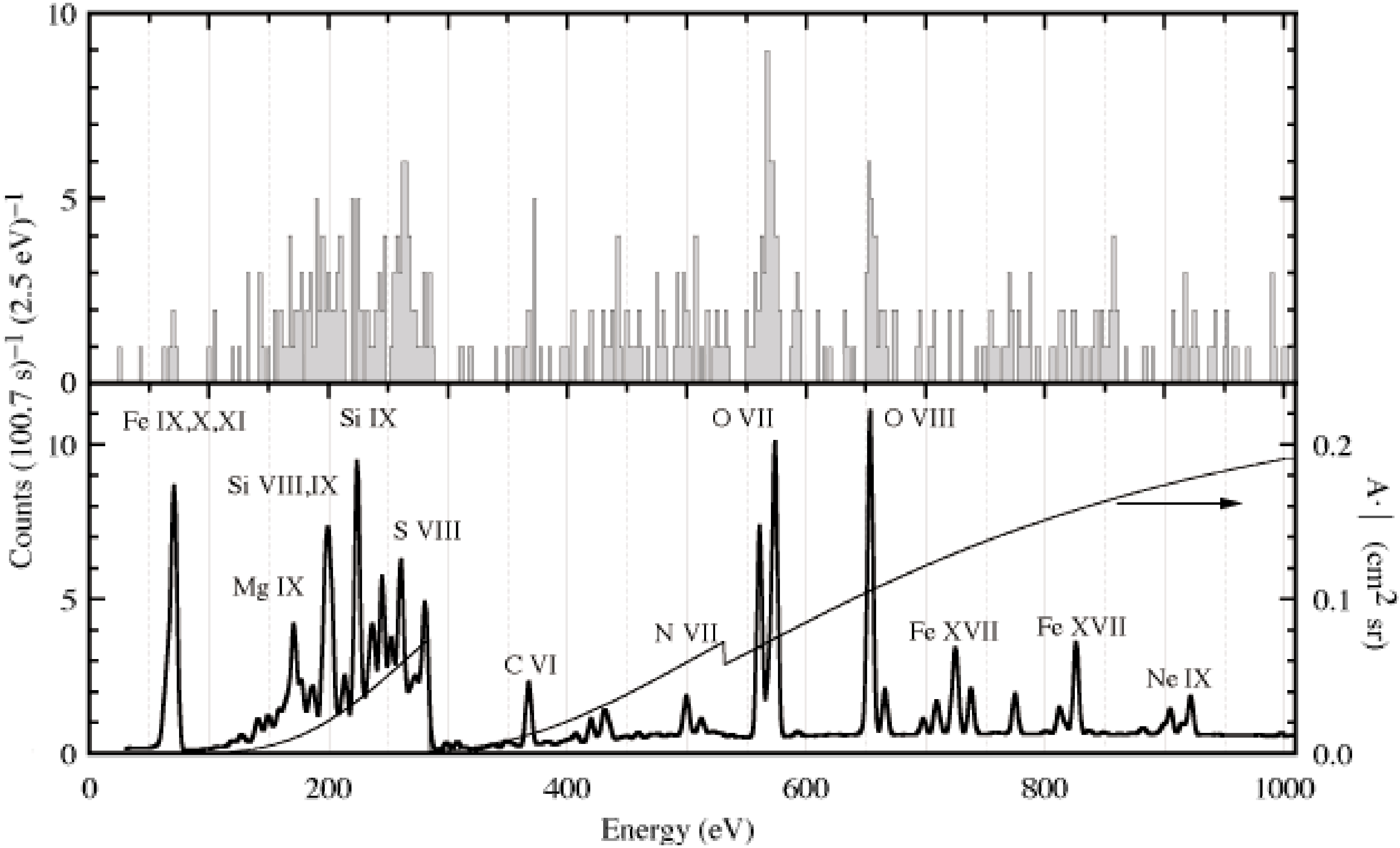


Measured CXE Cross Sections



(Hoekstra et al. Greenwood et al., Beirsdorfer et al., ...)

Soft X-ray Background Calorimeter Spectrum



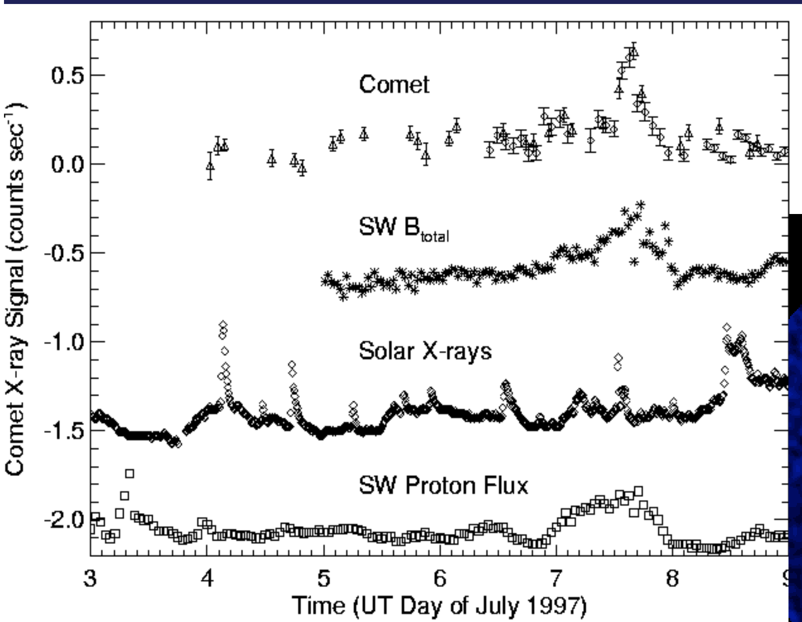
- Sounding rocket flight by McCammon et al. 2002
- 100 second integration of dark sky at ΔE =12 eV
- Line energies consistent with CXE cometary excitation
- We expect a similar CONX cometary spectrum

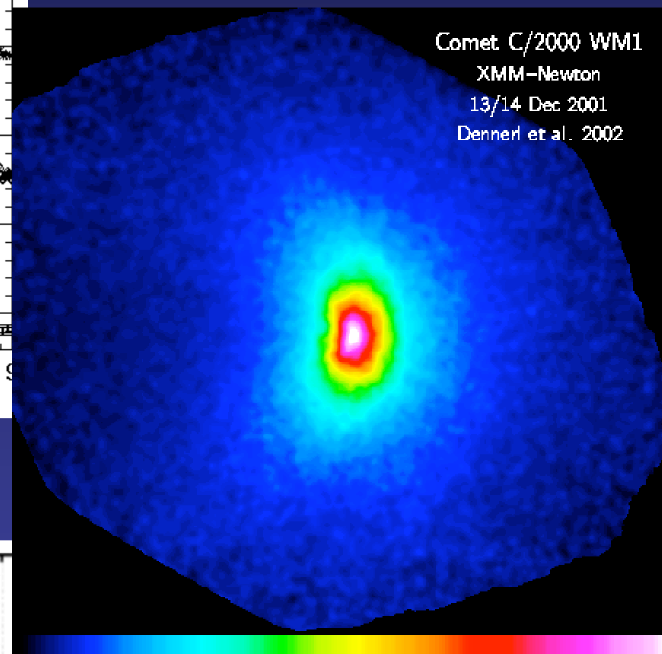
Desirements for CONX Observations of Cometary and Solar System CXE (priority order)

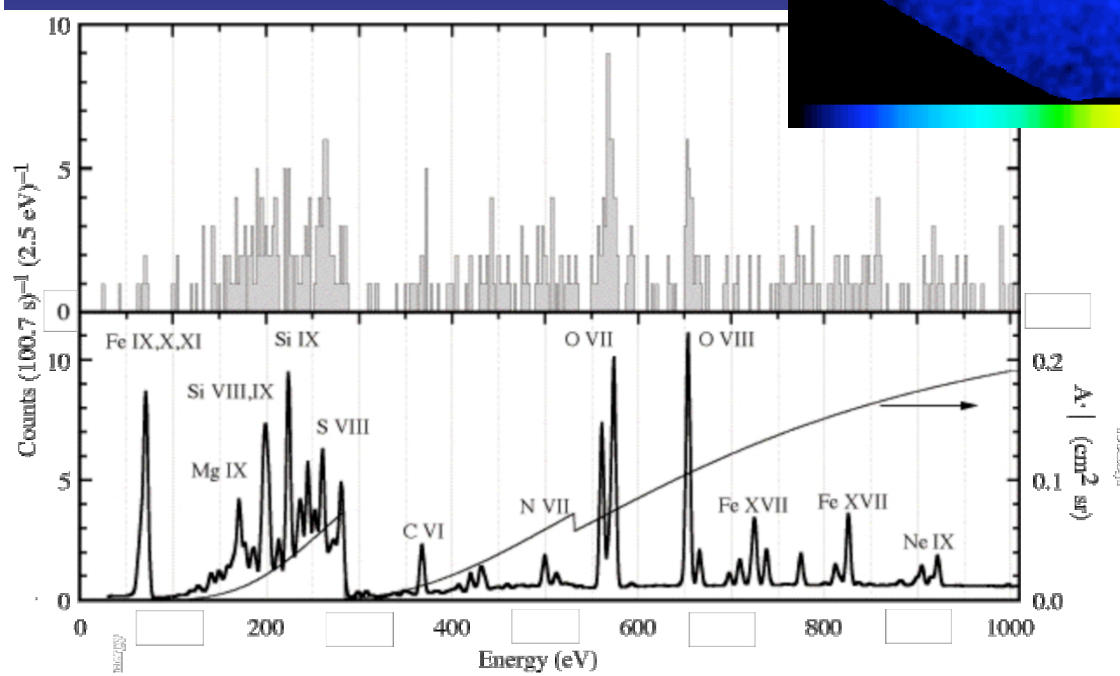
(N..B. all the below goals should be obtainable w/ the calorimeter detectors)

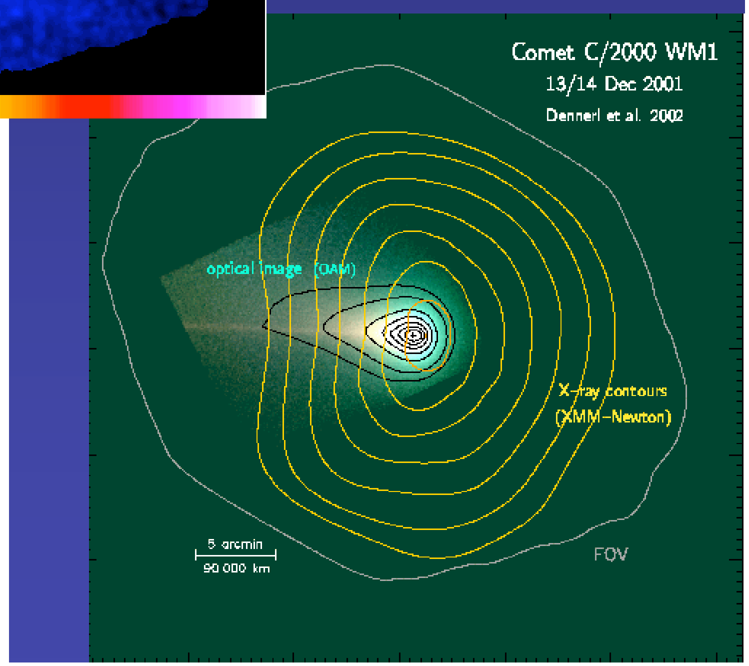
- 0.15 - 1.0 keV spectral imaging w/ SXT
- 5 eV spectral resolution for extended sources
- 1000 cm^2 effective area @ 200 eV
- Suppression of optical radiation to < 10^{-6}
- 2-3” spatial resolution
- Low count rate diffuse measurement capability down to 10^{-3} cps
- Multi-day monitoring capability @ few hrs/day
- Contemporaneous optical monitoring
- Wide FOV (~2’ x 2’ ?)
- Non-sidereal tracking, up to 1’/hr
- Small elongation constraint, down to 30^o desirable

What we expect to see in a CONX comet observation









Comments from the audience on presentation

•Solar system formation - x-ray phototchemistry (proto stars' observations)

•Neutral gas density measurement around other stars w/ stellar wind flux density

•Soft x-ray background studies important

•Not doable by Chandra/XMM; no proof to date of effect

•SS studies good, "cheap" PR; Can't sell mission, can kill it (?)

•Need to know vs Mars/Moon exploration roadmap - xray burden at Moon, Mars (how better than old in situ measurements? (spec,sens)

•Current measurements are photon # starved, need long baselines, lower energy sensitivity

•Use DRM proposals to motivate writeup

•Prioritize druthers and send to Jay Bookbinder (grating has poor spatial resolution, calorimeter has good spatial, poorer spectral)

Suggested CONX Theme :Star Formation & Stellar Coronae

- Stellar coronae still not understood (sum of microflares?) how does energy get from star into coronae
- Herbig Haro objects - detected in the x-ray
- Large burden of x-rays on proto-stelalr material => x-ray driven photochemistry important

- Other themes (beyond Einstein, Astro-Cosmology):
  - Formation of the Universe - GR tests
  - Equations of State - Dark Matter/Energy

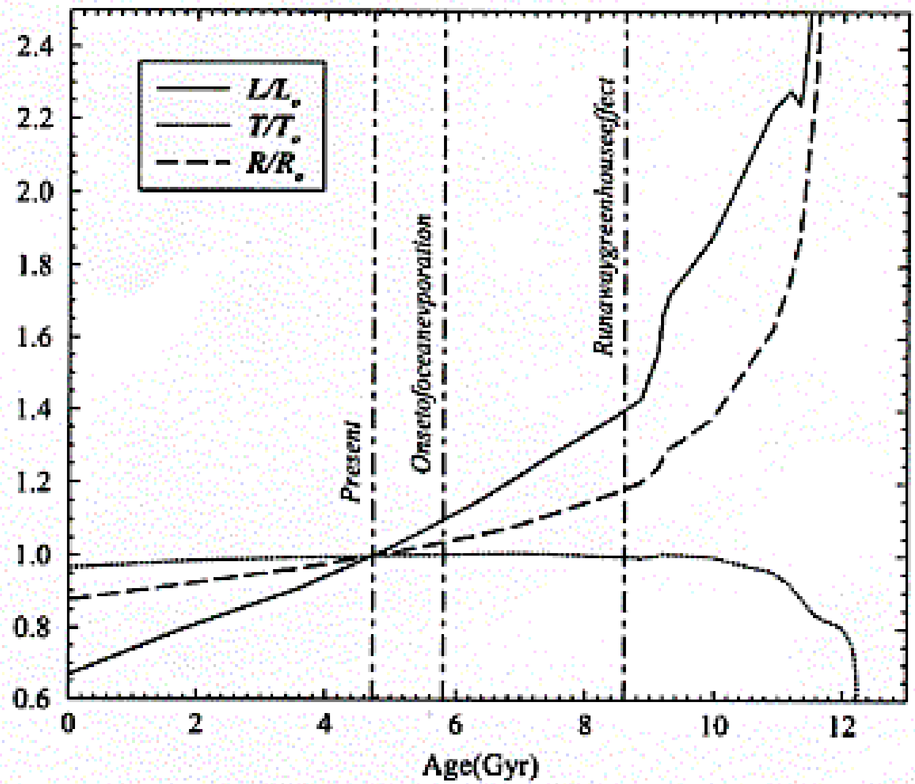


Figure 1. The evolution of the effective temperature, radius, and luminosity of the Sun from the zero-age main sequence to the start of its red giant phase. The vertical lines mark the approximate expected occurrences of Earth-related phenomena such as the onset of ocean evaporation and the start of the runaway greenhouse effect. Based on the evolution models of Bressan et al. (1993) and the predictions by Kasting (1988).

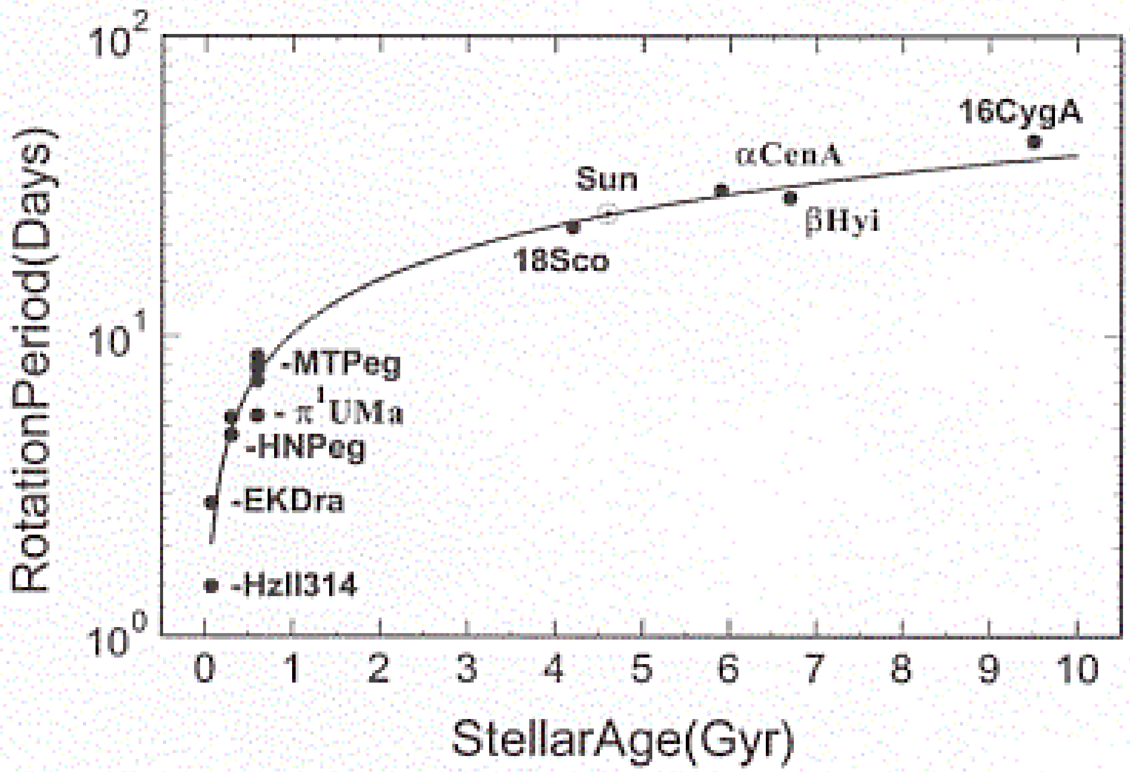


Figure 9. Plot of the rotation period vs. stellar age for a sample of solar-type stars (including the Sun). The solid line corresponds to a power law fit and indicates a spindown of solar-type stars with increasing age.

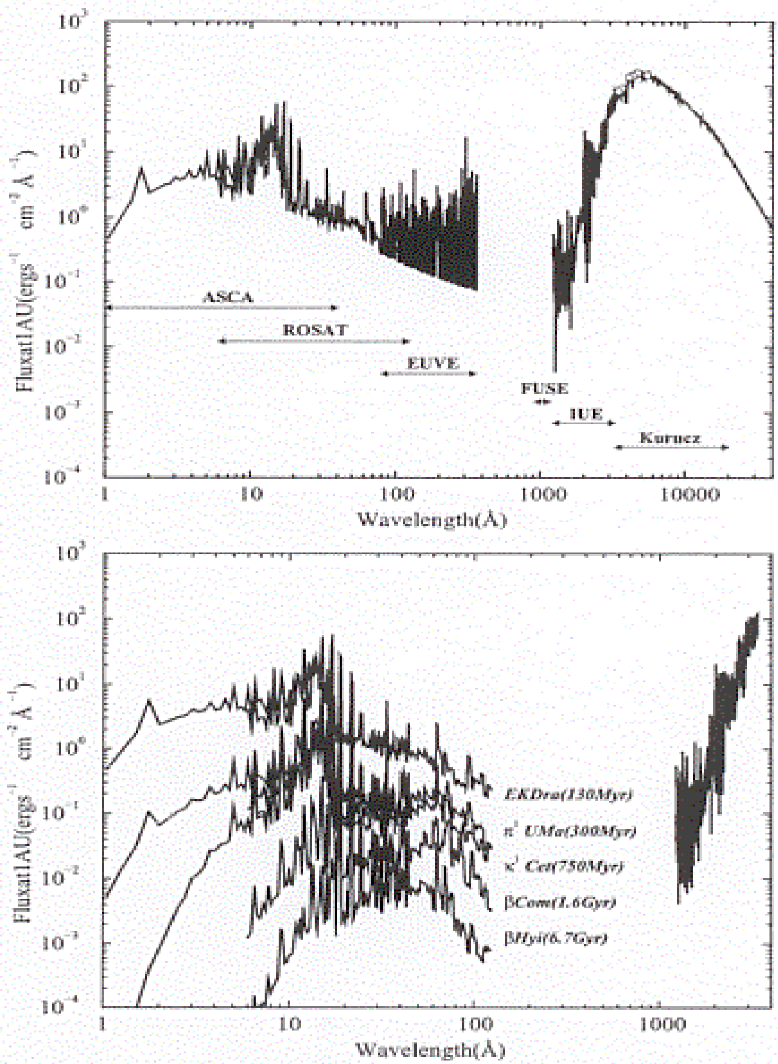


Figure 10. *Top:* Complete spectral irradiance for EK Dra, the youngest star in our sample. The plot represents the flux at 1 AU as a function of wavelength. The wavelength ranges of the different instruments/methods used are represented at the bottom of the panel (see Table 3). The EUVE fluxes have been corrected for ISM absorption. Note the the high flux at short wavelengths. *Bottom:* ASCA, ROSAT, and IUE irradiances for the five stars with complete data. Represented here is flux at 1 AU vs. wavelength. While the NUV/optical flux is similar for all stars, very large differences exist in the high-energy portion of the spectrum. These differences are very well correlated with the age and rotation period of the star.

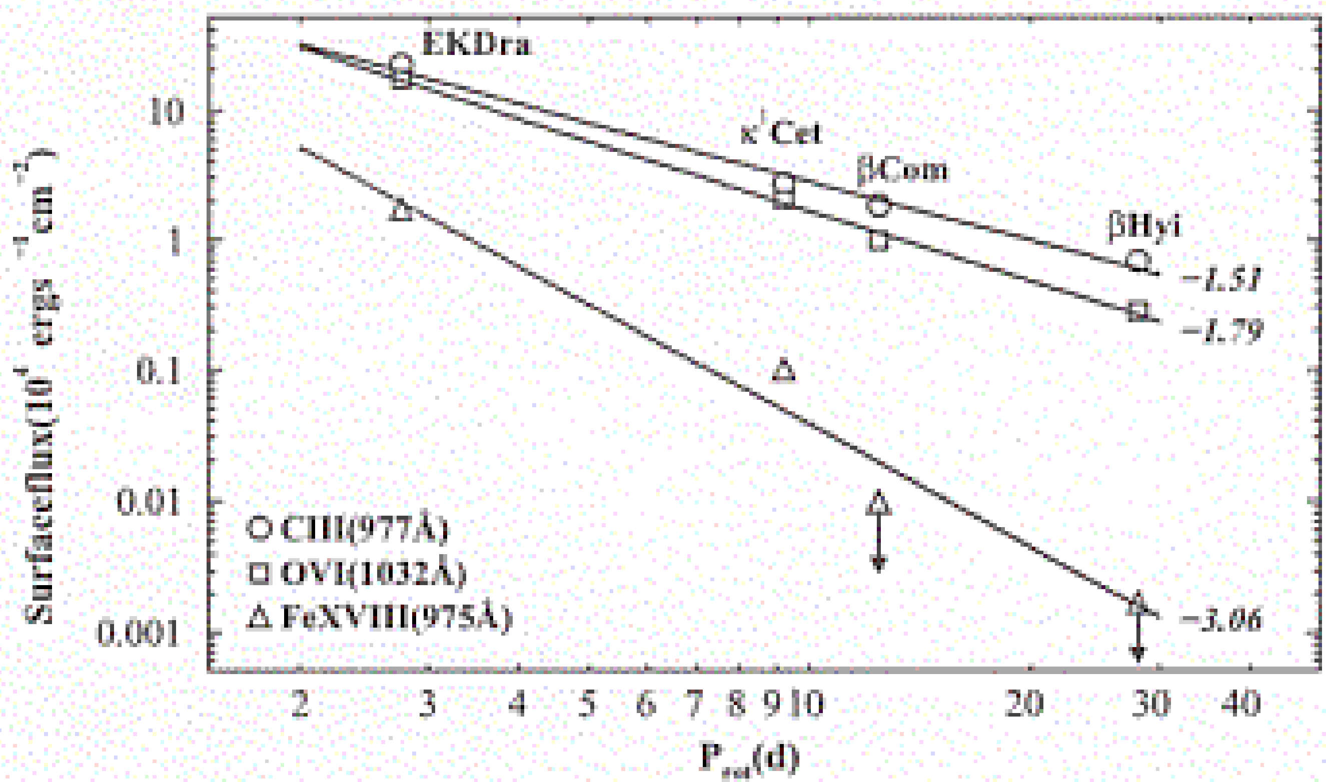


Figure 12. Integrated surface fluxes of C III 977 Å, O VI 1032 Å, and Fe XVIII 975 Å for some of our FUSE targets as a function of rotation period. The straight lines are power law fits to the measured data. The coefficients of the three fits are printed at the right end of the panel.